GUIDE FOR EDUCATORS AND AMATEUR ASTRONOMERS: BUILDING A FORWARD SCATTER METEOR DETECTION SYSTEM

There have been several requests from educators and amateur astronomy enthusiasts for information on this system. The following information may be used to setup a simple but effective forward scatter meteor radar system and collect useful scientific data.

Most amateur forward scatter radar systems use distant FM broadcast stations as their source. They tune to a quiet channel and hear a blast of music or talk when the ionization trail from a meteor completes the communication path. This uses very simple equipment (car radios are common) but is difficult to determine the meteor waveform and do any quantitative analysis of the signals. The technique documented here exploits the relatively stable, continuous signal from a TV station video carrier by demodulating it with a CW or SSB detector.

This information is not designed to be a complete tool, but more of a guide allowing one to substitute different pieces of equipment that might already be available and tailor the design and operation to maximize the effectiveness, based on location and the relative distance from various television signals.

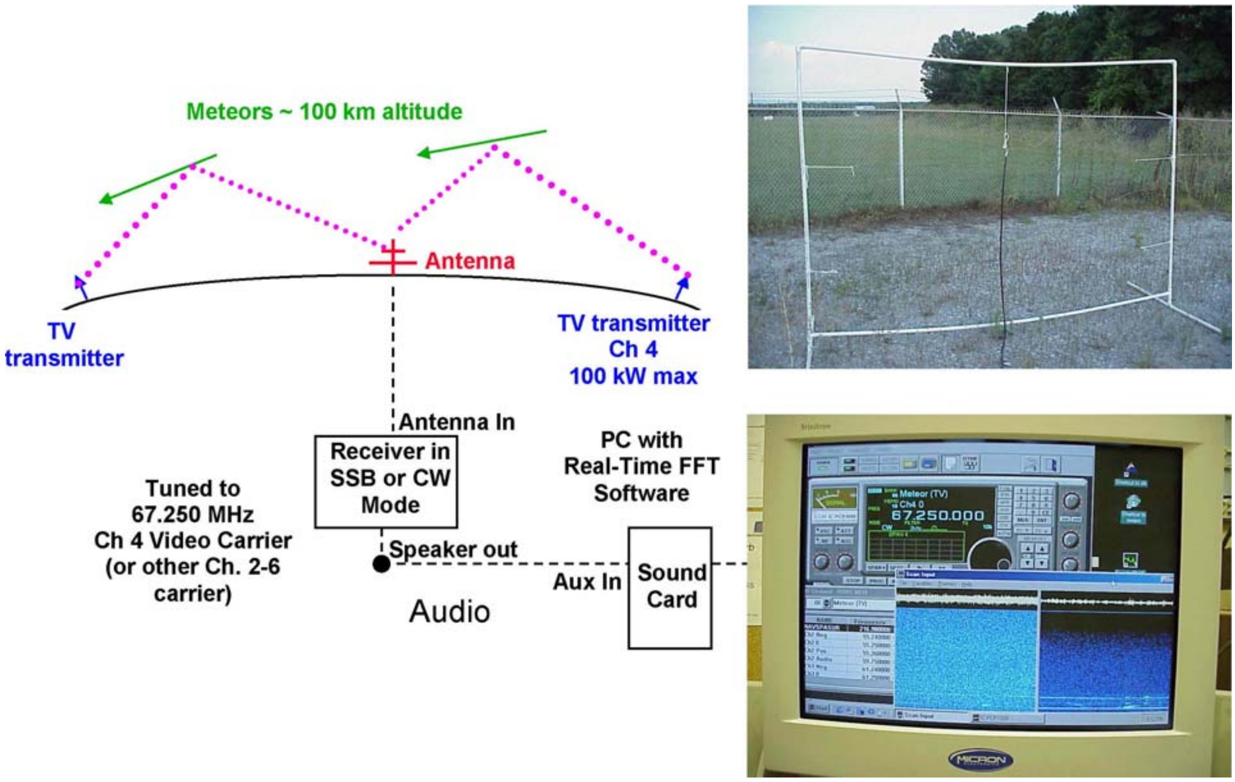
No attempt has been made here to describe the science involved in a meteoroid entering the atmosphere and reflecting a radio signal. Information on the science of meteor scatter of radio waves may be found in numerous papers accessible through the Astrophysical Data System (http://adswww.harvard.edu search for "meteor radar"). This guide strictly confines itself to the construction and operation of a forward scatter radar system.

As this is our first attempt at putting this information on paper, there may be a number of areas that are incomplete. If this is the case, please contact the Meteoroid Environment Office (MEO) via e-mail and we will be happy to help you through the problem area. (This will also allow us to refine this guide and make it better for future users.)

On a final note: If developing a forward scatter radar and using it to detect meteors becomes a favorite instructional module in school systems across the United States (and potentially the world), there may be some interest within NASA to remotely obtain the meteor count data from participating schools. This may mean the development of something similar to a "WeatherBug" station where participating schools would have their station counts on-line for anyone to view and for NASA to retrieve electronically. Right now this is only forward thinking, however, and no money has been identified for this purpose.

Necessary Items

- General coverage radio receiver capable of tuning TV channels 2-6 (54-88 Mhz) with CW or SSB demodulator Antenna
- Commercial TV antenna or build-it-yourself
- PC compatible computer w/sound card
- Required cabling
- Fast Fourier Transform and Meteor Counting Software – available from the MEO by request



(Meteor radar setup)

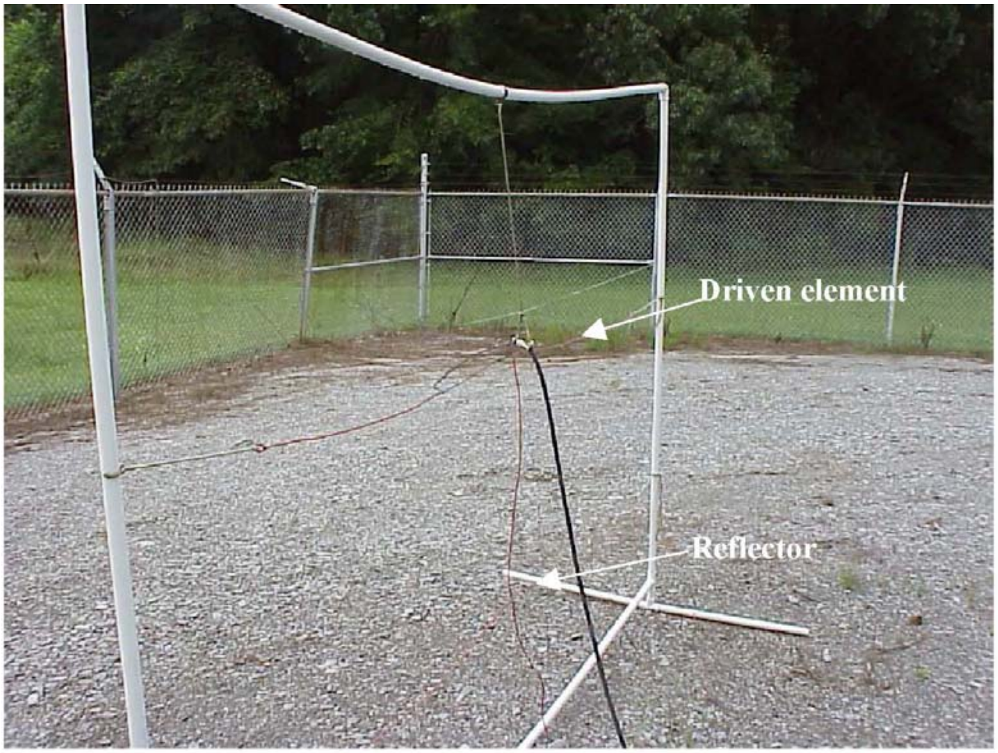
Receiver

There are a number of different receivers that can be used for a meteor radar. The only real requirement is that you can tune to 54-88 MHz and demodulate a SSB (single side band) or CW (continuous wave – or Morse code) signal. We have found that the ICOM computer-controlled PCR-1000 works very well. You can purchase an ICOM PCR-1000 from most any ham radio supply house. They are currently selling in the $350-$400 range. We have also used the more expensive ICOM R8500 receiver. Most of the amateur radio manufacturers produce receivers with the appropriate capabilities. A web search for general coverage receivers will turn up numerous vendors.

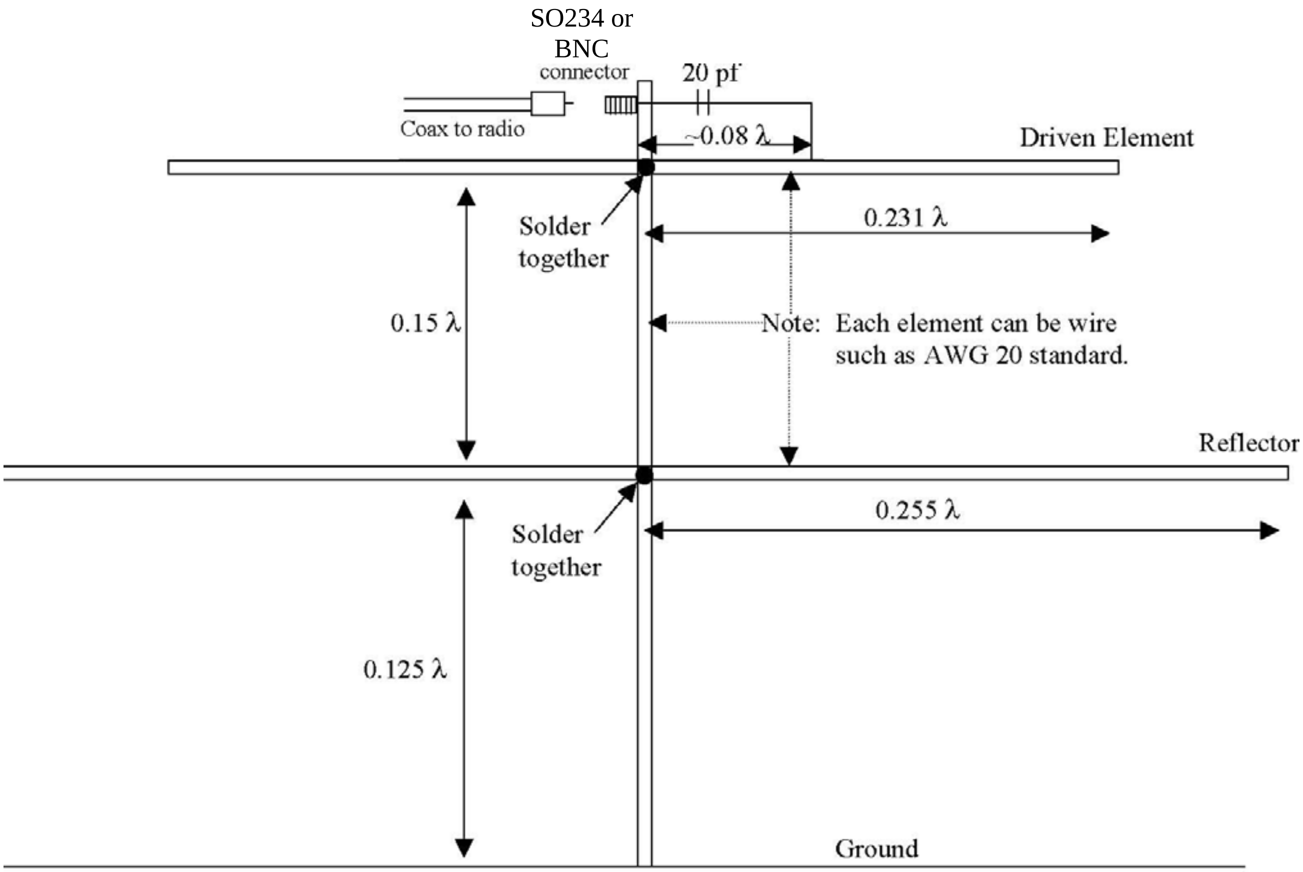
Antenna

Since we are receiving television video carrier signals, any TV antenna will work. We have used plain old rabbit ear style antennas for our portable operations during our Leonid optical observation campaigns. We have found that a simple 2 element Yagi antenna provides the best gain/field of view combination but have also used a higher gain 6 element cut-to-frequency commercial TV antenna. A good compromise is a VHF or VHF/UHF multi-element TV antenna like those available from Radio Shack. Frequency selection is discussed later in this document. In order to receive meteor echoes from any transmitter on the chosen frequency, the antenna should be pointed toward the zenith (directly overhead). This works best for us since there are several transmitters placed around us in the southeast U.S. If you live in an unpopulated part of the country, you may want to point the antenna toward the horizon in the direction of your chosen TV transmitter. You shouldn't be able to hear the video carrier unless a meteor occurs in the proper part of the sky.

The pictures below shows a simple wire 2 element Yagi suspended on a PVC pipe frame. The diagram following them gives the dimensions and details. The gamma match was calculated from the YagiMax software and adjusted for minimum standing wave ratio using an antenna analyzer. If you are not familiar with antenna construction and adjustment, contact your local amateur radio club and request the help of a ham operator. They know all about this stuff and would be delighted to help.


Driven element
Reflector


Two 40pf mice capacitors in series
To give 20pf



Calculating λ (using Channel 4 video carrier as an example)

Formula

$\lambda_{[cm]} = \frac{C}{freq[Hz]}$

λ = wavelength of interest

$C = 3 \times 10^{10}$ cm/sec

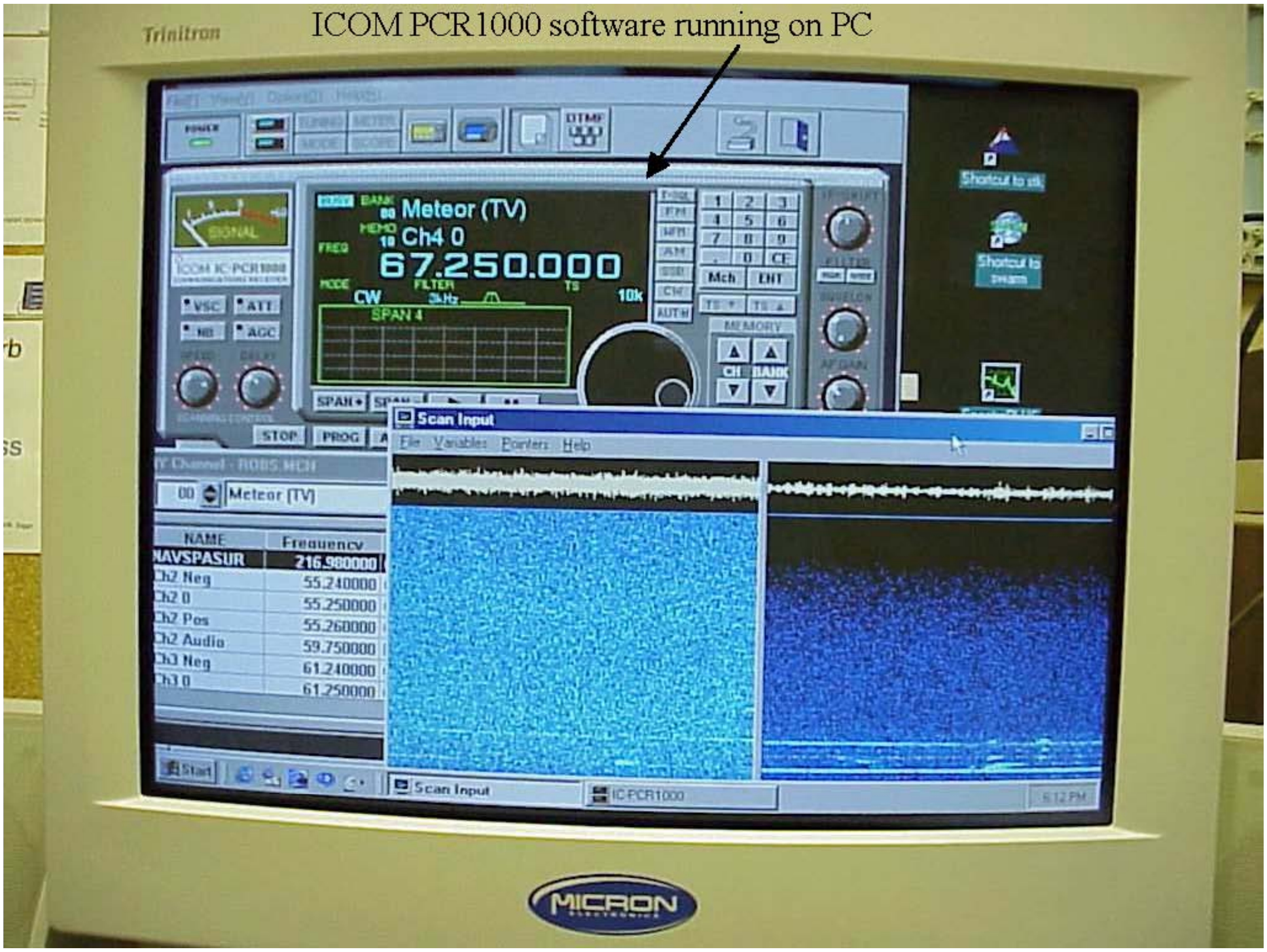
Freq $= 67.25 \times 10^{6}$ (Ch. 4 video carrier 67.25 MHz)

Example: $\lambda_{[cm]} = \frac{3 \times 10^{10}}{67.25 \times 10^{6}} = \frac{30000}{67.25} = 446.1$ cm

Note that in the pictures, the antenna is supported with a PVC frame and rope. An antenna like this shouldn’t cost more than $20 to build.

If you need additional help, try this website: http://www.kwarc.on.ca/tech/j-pole.html. It has directions on how to build an antenna as well.

PC With Sound Card



One of the nice things about this setup is that it will run on a 486 computer. However, you would be better served with a Pentium II or better running at 450Mhz or higher. A sound card is necessary because that is how the audio data from the receiver is transferred in. You will also need an RS232 port on the computer to connect to the PCR-1000 for configuration. The photo above shows the PCR-1000 control screen and the frequency display from the SpectroGram FFT software (available on the Internet).

Cabling

To connect the system together, you will need the following:

1) Coax cable to connect the receiver to the antenna

(Back of PCR-1000 receiver)

2) RS232 cable to connect the receiver to the computer, if using a computer-controlled receiver. (Note: This cable comes with the PCR-1000 receiver)

3) Mini stereo male-male to connect the receiver audio output to the sound card in your computer.

Tuning Your Receiver

There are several things you need to take into account when deciding what frequency to tune your receiver to. Ultimately a little trial and error will be required to get the optimal setup. The most important consideration is that the received power from a meteor is proportional to the cube of the wavelength. So, the lower the frequency, the better. In practice, the lower VHF range of TV stations, channels 2 – 6, are the best. Going to the higher frequencies reduces the strength of the meteor echoes; you may have to if you live in a highly populated area where there are strong carriers on all the low VHF frequencies. Remember, you want a frequency where you can't hear any strong carriers until a meteor meets its fiery demise.

The first thing you want to do is get an idea of the television transmitting stations around you. Frequencies of stations in the immediate area will not be good to use as the signal will swamp any returns you may get. The frequency of stations a few hundred miles away work very well. At MSFC, we chose the channel 4 zero offset video carrier, which is 67.25 MHz.

Additional information on all of the television frequencies and frequency allocations can be found at the following website:
http://www.tvtower.com/Commercial%20Television%20Frequencies.html

Included in the Forward Scatter section of the MEO website is an Excel file with all the channel 2 – 6 VHF TV stations in the U.S., Canada, and Mexico. The spreadsheet contains 2 worksheets: "Rcvr Location" should be updated with your latitude and longitude then "TV database" will contain all of the TV stations and their ranges from you. You can sort the worksheet by frequency, offset frequency, and range to find your candidate transmitting stations. Note that there are 3 video carrier frequencies associated with each TV station. They are the zero offset (xx.250 MHz), positive offset 10 kHz above (xx.260 MHz), and negative offset 10 kHz below (xx.240 MHz). The table below gives the zero offset carrier frequencies for several TV channels.

(A receiver tuned to the TV Channel 4 video carrier)

Channel	Range	Video Carrier	Audio Carrier
	MHz	0, +10, -10 kHz	
2	54 -60	55.25	59.75
3	60 -66	61.25	65.75
4	66 -72	67.25	71.75
5	76 -82	77.25	81.75
6	82 -88	83.25	87.75
7	174 -180	175.25	179.75
13	210 -216	211.25	215.75
14	470 -476	471.25	475.75
69	800 -806	801.25	805.75

(Television carrier frequencies)

If you tune to any of these frequencies and hear a loud buzz, you are too close to a transmitter on that frequency and need to try another one. In very populated parts of the country, it may not be possible to find a clear frequency.

If using a SSB detector, the receiver must be tuned about 1-2 KHz to one side (depending on upper or lower sideband) of these frequencies so an audio tone can be heard. A CW detector puts a tone at approximately 600-700 Hz when tuned exactly to the video carrier frequency. This is recommended.

At any given carrier frequency several tones offset by 10s to 100s of Hz may be audible. These are different TV stations. We have 4 to 6 different frequencies in our audio passband due to the various transmitters in the southeastern part of the U.S.. Find a frequency from the list above, which is relatively quiet, and listen for “pings” from meteors. These are most numerous near sunrise – this is a good time to tweak your system.

Software

“MSFC_radar_count.exe” is the counting software we have been using for a couple of years to count meteors. It is available from the MEO by request. It is built on “Sound Frequency Analyzer” available from http://www.relisoft.com/Freeware/source.zip and uses its sound card interface, FFT, and display code. We developed code to interface with it to look for the specific meteor waveforms and log them. The following is information provided to make installing and running the software easier.

When you install it on your PC, make sure that “met_cnt.ini” is in the same directory as “MSFC_radar_count.exe”. The output data files will be deposited in the same directory as the executable. There are 4 parameters in the first line of the “met_cnt.ini” but you may not need to change them. They are:

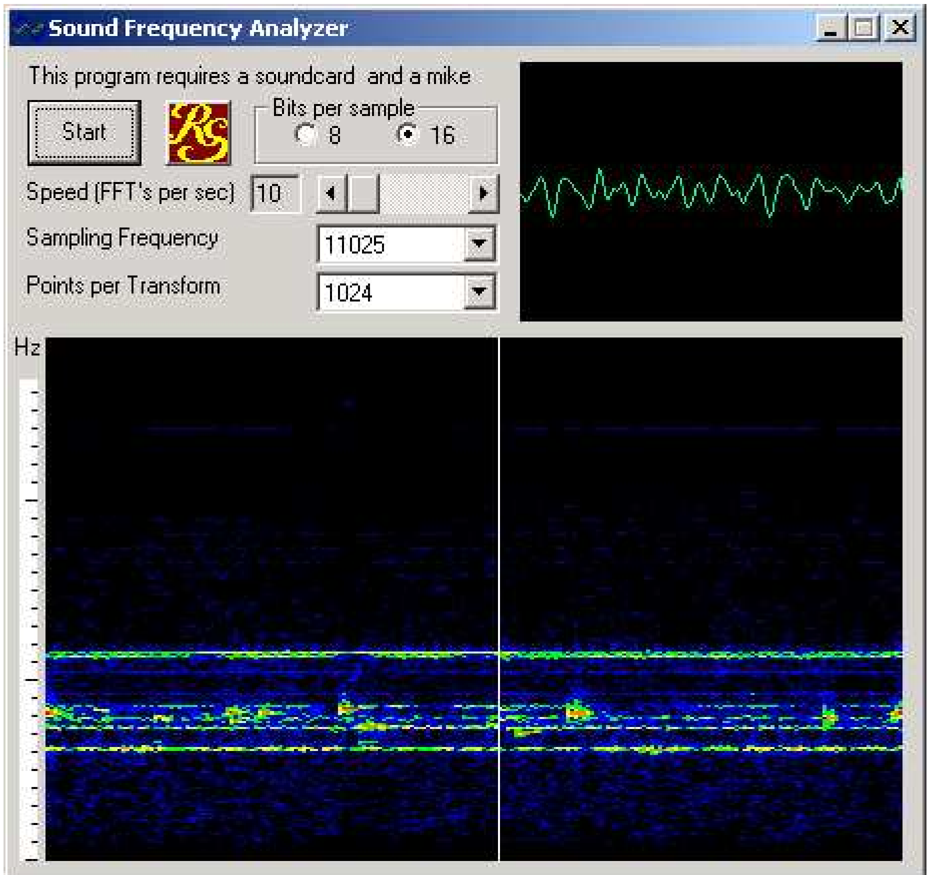
1) Beep .t. makes the computer beep at the same frequency where it detected a meteor. This is very useful to see if you have everything adjusted properly .f. turns off the beep

2) Gradient 4.5 is how steep the increase has to be for the underdense echo. Overdense (loud, long-lasting) echoes are not counted since their scattering geometry is indeterminant and they are not useful for scientific investigation of meteor rates.

3) Floor 35000. The peak of an echo has to be above this level to be considered as a meteor.

4) Bkgndceiling 10000. If the background is above this level, we have a big tropospheric signal coming in and we don't attempt to count at that frequency. We found that fluctuations in the tropo signal could lead to false counts.

There is one file generated when you start the program or at midnight by the PC clock.
Example:
28-JUL-03c.txt contains the counts. Every 15 minutes this is updated with a running count of the total number of meteors detected in 15 minute bins. There are 2 columns: decimal hour and 15 minute count of all meteors detected.



(Sound frequency analyzer)

MSFC_meteor_counts display output with several weak carriers (horizontal lines) and underdense meteors (yellow and red blobs)

Note: We only want to count underdense meteors. To do this the software, at each frequency and each time step, examines approximately 0.7 seconds of signal and looks for underdense characteristics. These characteristics are:

1) Peak above a certain threshold (35000)
2) Peak a certain factor above the background (3 to 5)
3) Echo monotonically decreases from peak (underdense meteor echo)
4) Background below a certain threshold (to avoid counting tropospherically propagated carrier modulation (10000)
5) Reject other “hits” within 1 second (avoids multiple counts of same meteor at different frequencies)

If 1 and 2 are satisfied, the waveform and time tag are saved to a file. If all are satisfied, it is flagged as a meteor and add to 15 minute count file. This technique rejects aircraft echoes (sinusoidal modulation) and lightning crashes (wrong waveform).

Adjust these parameters, adjust the audio output of the receiver, or “record” input of the sound card until you hear the software triggered beep. You can access the sound card controls by clicking the speaker icon in the system tray, clicking **options**, clicking **properties**, and clicking the **recording** radio button. Make sure the LINE or MIC input (whichever you are using) is enabled.

Important note: The software only examines frequencies between 200 Hz and 1000 Hz. If any echoes appear outside of this range, they will not be counted.

Conclusion

Hopefully, we have provided you with enough information to assemble and operate your own forward scatter meteor radar station. If you are an educator, this project can present your students many learning opportunities, so much so that it could cover an entire quarter of a school year or more. Some topics to explore are:

- Origin of meteoroids in space
- What happens when meteoroids enter the Earth's atmosphere
- Propagation of radio waves and how they interact with a meteor
- Engineering an antenna to receive the reflected signal reflected
- Why there is a diurnal variation in the number of meteors "seen" by the radar

Additionally, there is the opportunity to include computer science in the equation by having students attempt to build their own "meteor monitoring" software to plot and analyze the output of the counting software.

As noted earlier, with this being our first attempt at providing this to the educational community, we have undoubtedly left out many important details that seem matter-of-fact to us. Please help us make this package better by contacting the MEO when you have a question about something and then providing feedback to us if you actually use this information to complete a teaching module. Thanks.

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Additional Resources

1) International Meteor Organization radio observation information:
http://www.imo.net/radio/index.html

2) SpectraPlus software – free 1 month demo: http://www.telebyte.com/pioneer/

3) Spectrogram -software at: http://www.visualizationsoftware.com/gram.html

4) Frequency Analyzer 1.0 – free with C++ source code at:
http://www.relisoft.com/Freeware/source.zip
MSFC_meteor_count is built on this FFT software with MSFC-developed code to detect and count the meteor echoes at each possible frequency in the first 1000 Hz of the passband.